# TORNADO DAMAGE PATTERNS IN TOPEKA, KANSAS, JUNE 8, 1966

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ABSTRACT

An investigation of the damage resulting from the tornado in Topeka, Kans. on June 8, 1966 was conducted in an effort to determine the most protected areas of dwellings during this tornado. Inspection of 28 full basements under severely damaged houses and houses blown away revealed that some variation of unsafe areas did occur. The northeast section was somewhat safer than other locations although this was not statistically significant. Results based on observations of 17 walk-out basements showed that the north section of the basement was significantly safer than other locations. The walk-out basements faced the southwest which was also the direction from which the storm came. Investigation of the damage to the first floor of 90 houses which had both safe and unsafe areas showed the north and central sections were significantly safer than other locations.

## 1. INTRODUCTION

On June 8, 1966 at 7:15 p.m. CST about 50 people were attending a musical recital in MacVicar Hall located on the Washburn University campus in Topeka, Kans. Being aware that the area was included in a severe weather forecast they started for the basement when they heard the sirens and the roar of the huge funnel. Someone shouted, "to the southwest corner." In the confusion they sought shelter in the southeast part of the building. They were very fortunate in making this mistake since it saved their lives. The southwest section of the basement was immediately filled with tons of stones and debris by the tornado.

This incident and other somewhat similar cases provided the motivation for this study of the degree of protection afforded by the traditional southwest corner [1, 2, 3]. The resulting investigation of the houses damaged by the Topeka tornado was conducted in an effort to determine the protection from a tornado offered by particular sections of the basement and first floors of houses without basements.

## 2. DATA COLLECTION

The tornado funnel which passed through Topeka was about four blocks wide through most of the city. There was almost complete destruction of buildings along the 8-mile path extending from the southwestern edge of Topeka to the city limits on the northeast. The movement of the funnel was from the southwest. The tornado has been described as an almost average tornado [4] except for the fact that its path was across a city of 125,000 with a resulting large amount of damage but relatively few deaths. Other statistics as well as a map of the damage path across Topeka, photographs of damaged buildings, and a discussion of synoptic conditions are given by Galway [4].

Most of the houses in the tornado path did not have basements and many of the basements under damaged houses were entirely free of debris and, therefore, could not be used in the basement investigation. Since most of the houses in the damage area did not have basements, many people must have sought shelter in some other part of the house. It was estimated that 550 people were injured by this tornado with about 50 persons injured sufficiently for admission to the hospital. There were only 16 deaths in Topeka—14 of these from injuries during the tornado and two from heart attacks immediately following the storm. The location of the 550 people when their injuries occurred would be very interesting. However, this information would be more difficult to obtain and less informative than other data. Therefore, the investigation was directed toward the inspection of damaged houses in an effort to determine the areas which offered the most and the least protection during this storm.

The data for this investigation were obtained by inspecting the houses within the damage path of the storm. They fell within three groups: (1) houses with full basements with 1 to 4 ft. of the basement wall above ground level, (2) houses with walk-out basements built on a southwest-facing slope so that the southwest wall was almost entirely above ground, and (3) houses without basements whose first floors were inspected. Nearly all of the houses were square or rectangular in shape. Therefore, each basement or first floor was assumed to have nine sections obtained by dividing each outer wall into three equal parts. There were thus eight outer sections and one center or middle section of equal area. This did not in general correspond to the room partitions on the first floor which, of course, varied from house to house. Only houses which had both safe and unsafe areas were used in the investigation. Unsafe areas in the basements and on the first floor of houses without basements were determined by careful inspection. Sections were considered unsafe if they contained piles of boards or glass or chunks of the roof or walls so that a person would probably have been seriously injured if located in that area of the house during the tornado. In some cases it was difficult to determine whether the area would have been safe or unsafe. These areas were marked uncertain during the investigation and were not used in the final analysis.

In the entire damage area only 28 full basements were found which had both safe and unsafe sections. The two main reasons for this small number were the low percentage of houses which had basements and, since only basements with some unsafe area were used, the effectiveness of the basement in furnishing protection. Houses in the southwestern part of the city were all very similar in construction. These were the houses built on the southwest-facing slope which had walk-out basements. These houses were oriented at about a 45° angle with the primary directions. The southwest wall was almost entirely above ground level and the northeast wall was almost entirely submerged. These 17 walk-out basements were treated as a separate group in the analysis.

The investigation of the protection afforded by various areas on the first floor of houses without basements also included only those houses which were severely damaged yet had some protected area. Therefore, houses which were leveled by the tornado or two-story houses with only roof damage were excluded from the survey. Ninety houses were found to fit these criteria. This number of houses might appear to be a random sample of the estimated 810 dwellings with major damage. However, an effort was made to include all the houses in the damage path which corresponded to these requirements.

The location of each house which was inspected was recorded either by the address or by noting the distance of the house or basement from a particular street corner. The position of the house within the storm path was then determined from a map of the damage path. This was necessary because the damage path was about four blocks wide making it very difficult to determine the position of a particular house within the storm track from field observation. Each house was thus determined to be in the northwestern one-third, center one-third, or southeastern one-third of the damage track.

## 3. RESULTS AND DISCUSSION

### FULL BASEMENTS

The results of the investigation of the 28 full basements are shown in table 1. The largest percentage of the basements was located in the northwestern one-third of the storm path. A chi-square analysis was performed to determine the dependence of the distribution of unsafe sections on position within the storm track. This gave a value of 5.59 with 16 degrees of freedom which was not significant at the 95 percent level of confidence. Thus, there was no statistical difference in the distribution of unsafe areas in different parts of the storm. The first-floor investigation would be expected to be the most informative with regard to the dependence of the occurrence of unsafe sections on position within the storm. However, the results of this investigation, to be discussed later, also showed no significant effect on the distribution of unsafe areas of different locations within the tornado funnel. This is encouraging since a person interested in protection from an existing tornado would probably not know what part of the funnel was approaching. It should, therefore, be appropriate to consider the relationship between location within the basement and the total number of unsafe sections obtained by summing those in separate thirds of the storm path. Of the total number of unsafe areas, the south-central section of the basement was unsafe twice as frequently as the northeast section of the basement. Other characteristics of the distribution of unsafe areas are shown in figure 1. The respective percentages are plotted for those sections which had the least and the greatest frequency of unsafety.

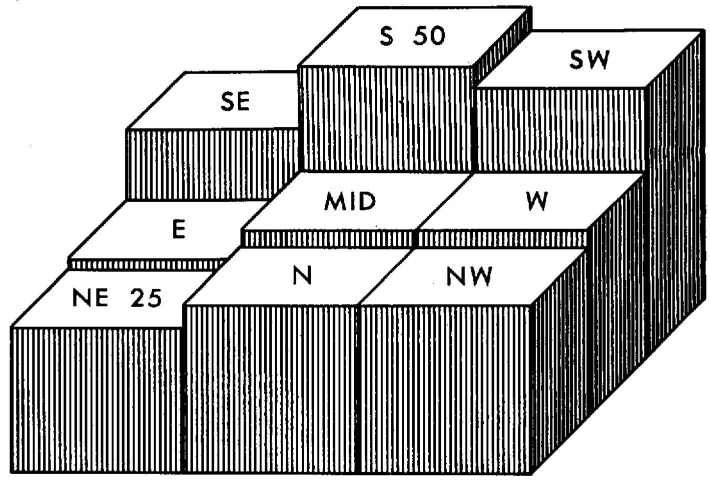


Figure 1.—The distribution of unsafe areas in the full basements investigated. Topeka tornado, June 8, 1966.

It was repeatedly observed during the investigation that the south sides of houses located in the middle and

Table 1.—*The frequency of occurrence of unsafe sections of basements located in different positions within the storm path, Topeka tornado, June 8, 1966*

| Section of the basement | Location within the storm path | | | |
|---|---|---|---|---|
| | NW third | MID third | SE third | Total |
| SW | 8 | 4 | 1 | 13 |
| S | 8 | 5 | 1 | 14 |
| SE | 6 | 4 | 1 | 11 |
| E | 6 | 2 | 0 | 8 |
| NE | 5 | 2 | 0 | 7 |
| N | 7 | 2 | 0 | 9 |
| NW | 7 | 2 | 0 | 9 |
| W | 7 | 2 | 1 | 10 |
| MID | 7 | 2 | 1 | 10 |

FIGURE 2.—An apartment house battered by the tornado with debris against the south side.

FIGURE 4.—An example of a basement which offered protection in all sections except near the south windows.

FIGURE 3.—A house sufficiently moved on its foundation so that the southwest corner dropped into the basement.

southeastern parts of the damage path were battered by debris carried by the wind. Inspection of many houses in the northwestern part of the storm path did not reveal any similar bombardment of the north sides of the houses. This observation is in agreement with the findings of Budney [5] who made a detailed investigation of the direction of tree fall during a tornado. The damage patterns in his study showed that trees fell in the general direction of the storm movement on both sides of the center of the damage path. Exceptions occurred as the tornado funnel lifted off the ground. In this case a convergent pattern of wind direction was indicated toward the point where the tornado lifted. Figure 2 shows the amount of debris which battered the south side of an apartment house. The impact was sufficient to cave in some of the above-ground portions of the basement wall. Other basements which had south windows were sometimes unsafe even with no loss of walls because so much debris had blown through the windows.

Figure 3 is another example which was repeated several times. The whole house was shifted toward the northeast enough to allow the southwest corner of the house to fall into the basement. When this happened the north part of the basement had much less debris than did the south. This occurred primarily in houses whose foundations were constructed from concrete blocks or stones.

Unsafe sections of the basement other than those exposed to the south were subjected mainly to debris falling through the floor. This seemed to be somewhat of a random occurrence and therefore very hard to generalize. Figure 4 is included as an example of the way many of the destroyed houses looked. Persons in the basement and away from the south windows would have been completely safe.

The significance of the relationship between frequency of unsafety and location within the basement was evaluated by computing a chi-square, making the hypothesis that there was equal probability of occurrence of unsafe sections in any location in the basement. The computed chi-square in this case was 4.15 with 8 degrees of freedom. This value was not significant at the 95 percent level of confidence, indicating that the frequencies of unsafe areas shown in table 1 are not significantly different from a random distribution for this number of observations. Therefore, little confidence can be placed in the application of this distribution of unsafe areas to tornadoes in general.

## WALK-OUT BASEMENTS

The results of the investigation of 17 walk-out basements are shown in table 2. These houses were all in the same district and were very similar in construction. Each was located on a southwest-facing slope so the southwest wall was almost entirely above ground level and the northeast

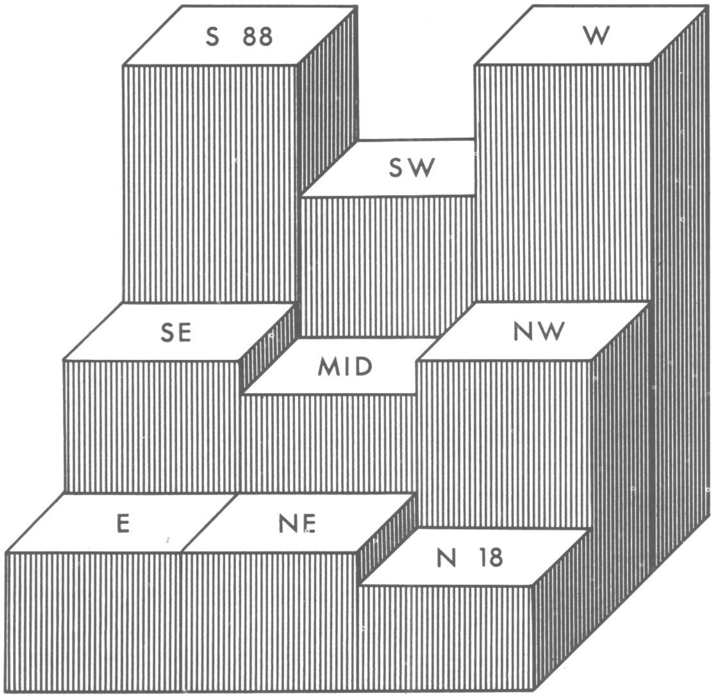


FIGURE 5.—The distribution of unsafe areas in the walk-out basements.

FIGURE 6.—The southwest side of a walk-out basement.

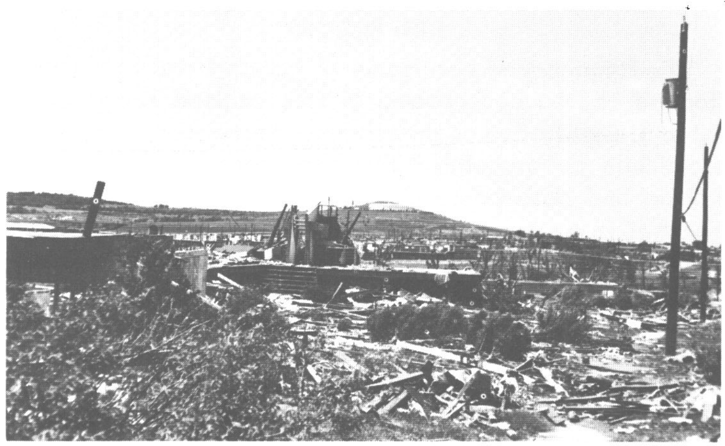

FIGURE 7.—The northeast side of a walk-out basement showing the protected north corner.

wall was almost entirely submerged. The southwest side had large windows near each end and two doors near the center. The tornado came from the southwest and almost all of these houses were in the middle of its path. The number of houses in the northwest and southeast thirds of the storm path was insufficient for an analysis of the dependence of distribution of unsafe areas on location within the storm. There is, however, no apparent relationship shown in table 2 and since the other basements and the first floor investigation showed no significant association, the total number of unsafe sections will be considered. The distribution of unsafe sections in the walk-out basements is shown in figure 5. Only 18 percent of the houses were unsafe in the north section, while 88 percent of the houses were unsafe in the south and west sections.

Nearly all of the houses in this group were damaged in the same manner by the tornado. Debris battered the southwest side of the house and came through the walls or windows into the south and west sections. The ceiling above the southwest rooms of the walk-out basements was blown away in nearly all cases while it frequently remained over the north section. The southwest and northeast sides of two of these houses are shown in figures 6 and 7.

TABLE 2.—*The frequency of unsafe areas in the walk-out basements located in different positions within the storm path, Topeka tornado, June 8, 1966*

| Section of the basement | Location within the storm path | | | |
|---|---|---|---|---|
| | NW third | MID third | SE third | Total |
| SW | 1 | 10 | 0 | 11 |
| S | 2 | 12 | 1 | 15 |
| SE | 0 | 8 | 0 | 8 |
| E | 0 | 4 | 0 | 4 |
| NE | 0 | 4 | 0 | 4 |
| N | 0 | 3 | 0 | 3 |
| NW | 0 | 8 | 0 | 8 |
| W | 2 | 11 | 2 | 15 |
| MID | 0 | 7 | 0 | 7 |

The significance of the relationship between location in the walk-out basements and the frequency of unsafety was evaluated by a chi-square analysis similar to that for the full-basement investigation. The assumption of equal probability of safety in all locations within the walk-out basements was made. This gave a chi-square value of 19.68 with 8 degrees of freedom which was significant at the 95 percent level of confidence. This means that the values shown in table 2 are significantly different from a random distribution and that this distribution of unsafe areas in walk-out basements may have general application. The distribution would not be expected to apply to walk-out basements with a different orientation, however.

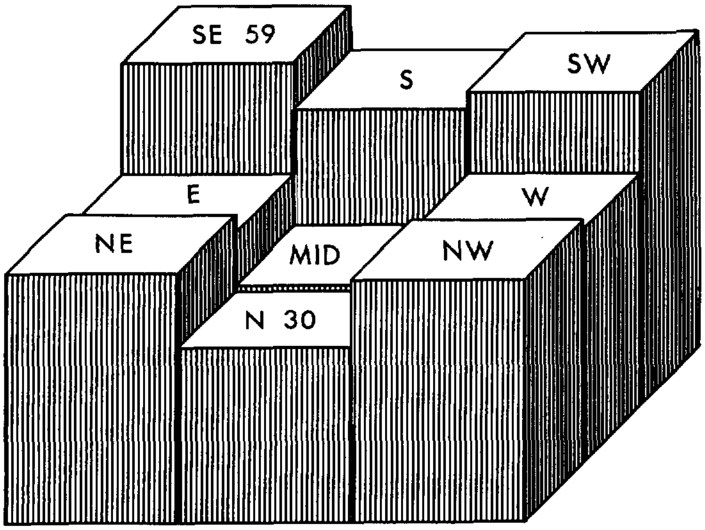


FIGURE 8.—The distribution of unsafe areas on the first floor.

### FIRST FLOORS

The frequency of occurrence of unsafe areas on the first floor of the 90 houses used in this analysis is shown in table 3. Eighty-five of these houses were constructed from wood and the remaining five from brick. Each of these houses had both safe and unsafe areas on the first floor. Some of these houses were one-story structures and others were two-story houses which were damaged sufficiently that at least one section on the first floor was unsafe. The stone structures on the Washburn University campus were also investigated but were not used in the analysis since it was felt that they constituted a fourth group. The number of these buildings was insufficient for an evaluation, however.

The effect of location within the storm path upon damage distribution within a given house might be expected to be more important for the first floors than for the basements. Houses located in the northwest third of the funnel might be expected to have more damage to the north part of the houses since this should be the windward side because of the cyclonic circulation of the wind. A sufficient number of the houses were located in the northwest part of the damage part so that a chi-square analysis for the importance of location within the storm should give good results. The chi-square value of 4.42, with 16 degrees of freedom, was not significant at the 95 percent level of confidence. Therefore, the distribution of unsafe areas on the first floor was not significantly different for separate thirds of the storm path.

The distribution of unsafe areas on the first floor is shown in figure 8. The southeast section was unsafe most frequently and the north-central area was unsafe less often than other sections. A chi-square analysis of the frequency of unsafe positions, without regard to location within the storm path and assuming an equal probability of safety in all sections of the first floor, gave a value of 16.21 with 8 degrees of freedom. This value was significant at the 95 percent level of confidence. Therefore, an equal

TABLE 3.—*The frequency of unsafe areas on the first floor of houses located in different positions within the storm path, Topeka tornado, June 8, 1966*

| Section of the first floor | Location within the storm path | | | |
|---|---|---|---|---|
| | NW third | MID third | SE third | Total |
| SW | 19 | 25 | 5 | 49 |
| S | 15 | 26 | 5 | 46 |
| SE | 20 | 28 | 5 | 53 |
| E | 13 | 20 | 3 | 36 |
| NE | 15 | 20 | 4 | 39 |
| N | 10 | 13 | 4 | 27 |
| NW | 17 | 18 | 2 | 37 |
| W | 13 | 20 | 3 | 36 |
| MID | 8 | 16 | 4 | 28 |

probability of safety did not exist for all areas on the first floor. The most unsafe areas on the first floor were those exposed to the south. The southeast corner was unsafe almost twice as frequently as the north-central section which was only slightly better than the central area of the house.

Although no records were kept on the protection afforded by rooms of varying sizes it appeared that the smaller rooms were consistently safer. Bathrooms were frequently one of the safe rooms on the first floor especially when they were on the north side of the house or in the central area.

## 4. SUMMARY AND CONCLUSIONS

Results of the inspection of basements under houses severely damaged by the Topeka tornado of June 8, 1966, failed to reveal any statistically safest location. However, for this particular sample the protection offered by any section of the basement along the north wall was considerably greater than the protection near the south wall.

The investigation of walk-out basements which faced the southwest showed that the north area offered the most protection from the tornado.

The investigation of first floors of houses severely damaged by the tornado showed that the north and central parts of the house were statistically safer than other locations. If these results are applicable to other tornadoes it is important that the public be advised against seeking shelter from a tornado in the southwest corner on the first floor. Letters from some of those injured in this tornado indicated that this was the location that was chosen in the absence of a basement.

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